Advancing Circular Economy Practices in Aviation

By ICAO Secretariat

Introduction

As global aviation continues to evolve, the industry faces increasing pressure to mitigate its environmental impacts. Traditionally, many sectors, including aviation, have operated within a linear economy, a system in which resources are extracted, used to produce goods, and ultimately discarded before their full value is realized. In such a model, the lifecycle of a product typically ends with its disposal. However, with growing resource scarcity and an urgent need to mitigate environmental impacts, the linear economy is proving unsustainable.

In response, the circular economy presents an alternative approach by emphasizing waste reduction, material reuse, and maximizing resource value before disposal. Although the concept of a circular economy first emerged as an economic model over 30 years ago[1], its application within the aviation industry is still evolving. By rethinking the design, operation, and retirement of aircraft, as well as waste management at the airport or by the airlines, the aviation sector can leverage a circular economy to reduce its environmental footprint, enhance efficiency and lower costs.

Understanding the Circular Economy

A circular economy is essentially a system designed to preserve the value of materials and resources for as long as possible. In contrast to the linear economy, which follows a "take, make, waste" model of production and consumption, the circular economy prioritizes resource efficiency, waste reduction, and environmental regeneration.

According to the Ellen MacArthur Foundation[2], the framework of a circular economy is built upon three key pillars: waste reduction, the circulation of products and materials, and the regeneration of natural systems.

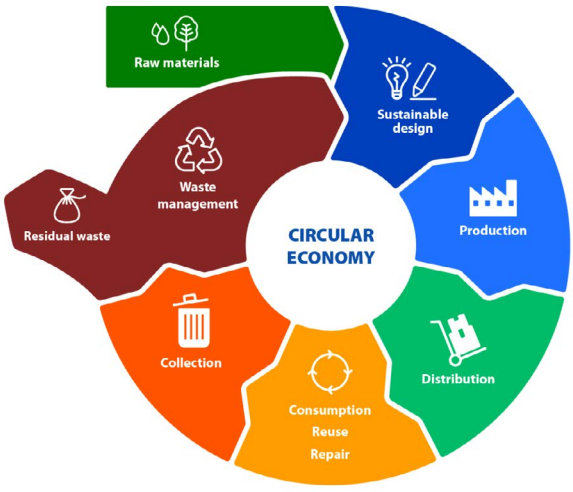

FIGURE 1: The Circular Economy Model (source: European Parliament Research Service)

1 Rizos et al., "The Circular Economy: A Review of Definitions, Processes and Impacts."

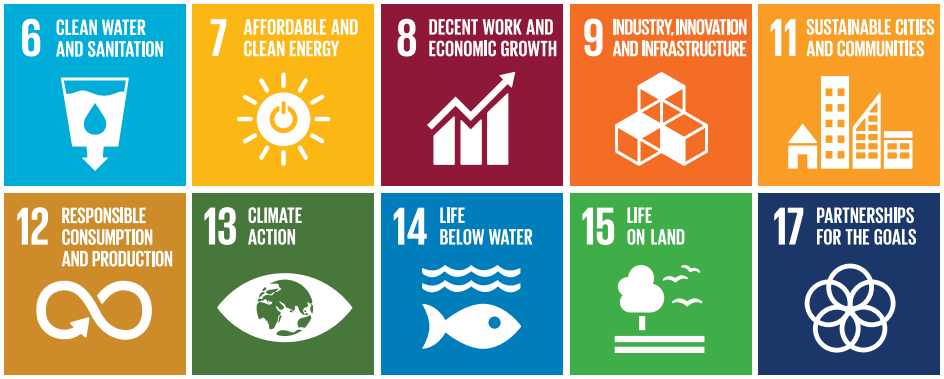

FIGURE 2: SDGs Related to the Circular Economy Model

First, waste can be reframed not as an inevitable byproduct of production, but as a design flaw. Transitioning to a circular system requires that goods, materials, and infrastructure be designed for durability. By intentionally focusing on longevity during product design, industries can eliminate unnecessary waste at its source, thereby reducing their environmental footprint.

Second, the circular economy emphasizes keeping materials and products in circulation for as long as possible. This approach extends the lifecycle of products through practices such as repair, refurbishment, remanufacturing and recycling. The goal is to maximize the use of finite resources, reducing reliance on virgin materials and minimizing energy-intensive processes involved in production.

The third pillar of a circular economy is the regeneration of natural systems. This goes beyond merely reducing waste by focusing on restoring and renewing natural environments, rather than viewing nature solely as a resource to be extracted. Adopting a regenerative approach allows us to replicate the natural process where waste does not exist, such as in composting, which returns biological materials to the earth.

The concept of a circular economy does not only exist within a theoretical framework. Several countries have begun incorporating circularity into their national policies. For instance, the Dutch government as outlined its objectives in the 2023–2050 National Circular Economy Programme, which emphasizes reducing raw material consumption, extending the lifespan of products and parts, and minimizing waste through advanced processing methods[3]. The Netherlands aims to achieve a waste-free economy by 2050. Similarly, Chile published a long-term circular economy roadmap in 2021, which includes goals such as creating green jobs, recovering illegal dumping sites, and increasing material productivity. This comprehensive plan integrates both upstream and downstream activities to build an efficient and actionable path toward circularity[4].

Importantly, applying circular economy principles is aligned with several United Nations Sustainable Development Goals (SDGs), namely those focused on responsible consumption and production (SDG12), climate action (SDG13), and industry innovation (SDG9). By keeping materials in use longer and reducing waste, circular strategies help mitigate environmental impacts while fostering a more sustainable economy.

Circular Economy in Aviation

Aviation is a resource-intensive industry, from reliance on high-value materials in aircraft manufacturing to the significant energy demands for global airport operations. Adopting circularity in aviation presents a strategic opportunity to reduce material dependency, extend the life cycle of inputs, and recover value from end-of-life assets.

While achieving full circularity in aviation is still a long-term goal, circular economy strategies are beginning to take hold across the industry. From the design, maintenance, and retirement of aircraft, waste management onboard by airlines, to resource management, waste reduction, and infrastructure reuse at airports, circularity is reshaping the aviation ecosystem. These strategies not only aim to reduce the sector's environmental footprint but also enhance efficiency, resilience, and long-term value recovery.

The aviation industry is set for significant growth in the coming years. According to ACI and ICAO, global air passenger traffic is forecast to surpass 12 billion by 2030. In 2024, revenue passenger kilometers (RPK) reached about $8.8 trillion, representing a 101% increase since 2019[5]. Additionally, Airbus forecasts that global air traffic with more than double (2.4) over the next 20 years[6]. This rapid growth underscores the need to implement circularity in aviation, as increased demand translates to higher resource use, waste, and emissions. By integrating circular economy principles, aviation can guide its growth toward more sustainable and efficient development.

These principles can be applied to both aircraft management, operators, and airport operations, setting the foundation for more circularity in aviation.

Regarding aircraft, maintenance, reuse, and recycling is a key strategy for promoting circularity and addressing the end-of-life of the aircraft after flying. For example, retired aircraft can be disassembled, with valuable materials such as aluminum and titanium recovered for reuse.

This approach not only supports environmental goals but is also more cost-effective. Advances in aircraft disassembly now allow for nearly 80% of components to be recycled, with over 90% of an aircraft's weight reused or repurposed. Approximately 40-50% of aircraft materials are reused for maintenance, while the remaining components are reintroduced into the supply chain as raw materials[7].

Airbus and Boeing were both early pioneers in aircraft recycling. Airbus launched the Process for Advanced Management of End-of-Life Aircraft (PAMELA) project in 2005, to encourage safe and sustainable aircraft decommissioning. In 2006, Boeing founded the Aircraft Fleet Recycling Association (AFRA) to establish standards for environmentally responsible end-of-life aircraft management. Over the past decade, several other companies have continued to innovate in this area. For example, in 2013, Southwest Airlines, in partnership with various non-profits, launched the "Repurpose with Purpose" initiative, which involves removing leather seat covers from retired planes and donating them to be upcycled into new products[8].

Recycling and upcycling in aviation are not limited to aircraft alone. In June 2023, Emirates introduced a closed-loop recycling initiative[9], where damaged plastic trays, bowls, and dishes collected from their cabins are processed and remanufactured into new in-flight meal service items. This initiative further demonstrates how circular practices can be applied across different aspects of aviation operations.

Circular economy principles must also be applied on the ground, as airports play a critical role in promoting circularity within aviation and can benefit significantly from doing so.

For example, in December 2021, Aeroporti di Roma unveiled its PIONEER[10] project, co-funded by the European Union, aimed at increasing sustainability at Rome Fiumicino International Airport. The project implements a system that uses second-life batteries from the automotive sector to store excess energy generated by a 30 MW solar photovoltaic plant. The energy collected during the day is then used to meet the airport's electricity needs during high-demand evening hours. By incorporating a renewable energy storage solution, the initiative provides greater flexibility and reduces dependence on fossil fuels. Notably, PIONEER is the first project globally to use second-life batteries from multiple original equipment manufacturers at this scale. It serves as a strong example of circularity by giving electric vehicle batteries a second life after completing their initial use cycle.

Improving waste management is another important aspect of implementing circularity at airports. San Diego International Airport has taken significant steps through its Zero Waste initiative, which aims to achieve a 90% waste diversion rate and a 10% reduction in waste per passenger by 2035[11]. Key measures include composting organic waste, digitizing communications to reduce paper use, switching to reusable dishware, and implementing xeriscaping (using drought-tolerant native plants to minimize water consumption).

Plastic pollution also poses a significant challenge within waste management. In aviation and hospitality, plastics are favoured for being lightweight and hygienic, but over a third of plastic products are used once in these industries. Producing plastics relies on petroleum, and they are non-biodegradable, creating environmental issues throughout their entire life cycle. While seeking alternatives to plastic is useful, this can also introduce new complexities. Therefore,

proper waste management of single use plastics (SUPs) is essential, and applying circular economy principles such as reducing use, designing for reuse, improving recycling processes and using more recycled materials, offers an environmentally responsible approach.

Airports are increasingly adopting sustainable practices to manage plastic waste. For instance, Colombia's El Dorado International Airport is advancing a Circular Economy Plan to reduce the use of virgin raw materials and increase reuse through their waste management process. Currently, 65% of its waste is revalued, with a goal of 70% by the end of 2025. By 2023, 78% of terminal waste was reused, and in 2022, the addition of 65 water refill stations helped avoid the use of over 1.7 million single-use plastic bottles that year alone.

Challenges and Support for Circular Economy in Aviation

While the integration of circularity in aviation has made significant progress in recent years, its implementation still faces notable limitations. A major component of circularity in aviation involves recycling retired aircraft, but this process encounters several challenges. For example, separating materials manually versus mechanically often involves a trade-off between quality and cost, making efficient recycling difficult. In addition, the presence of hazardous materials in aircraft further complicates safe disposal and recycling processes. Furthermore, recycling avionics, electronics, and advanced alloys like aluminum-lithium (Al-Li) and composites remain technically challenging.

Beyond material-specific issues, it is difficult to accurately assess the full scale of waste produced by the aviation industry, and some stakeholders may lack access to the advanced technologies and solutions necessary to implement circular economy practices effectively. To overcome these barriers, partnerships and support programs are essential, offering technical, financial, and political assistance, particularly to States most in need, to evaluate and implement circular economy initiatives at the local level.

In alignment with its *No Country Left Behind* initiative, ICAO has been actively raising awareness about circular economy practices in aviation. For example, ICAO organized the Seminar on Green Airports, held from 18–19 April 2024 in Athens, Greece. The Seminar included discussions on circular economy within aviation, alongside topics such as deployment and distribution of SAF, LCAF and other aviation cleaner energies at airports, financing environmental projects and mitigation measures, partnerships for a sustainable future, and adaptation measures to enhance the climate resilience of airports.

Furthermore, ICAO has provided practical guidance through the Eco-Airport Toolkit e-publication on Waste Management at Airports and the Toolkit on Single Use Plastics both of which support the implementation of circular economy practices in aviation. The Toolkit e-collection offers accessible information to aid in the development of airport infrastructure projects and environmental planning. Specifically, the waste management section outlines a three-step approach: 1) analyzing material flows; 2) identifying areas for improvement; and 3) implementing circular business models. These steps contribute to building a global platform for sharing the most effective and up-to-date technologies and applications of circular economy practices across the aviation industry. Meanwhile, the SUP publication outlines key considerations for addressing the prominent use of SUPs in aviation and provides guidance on how to reduce, manage and transition away from SUPs supported by best practice examples from the sector.

[1] Rizos et al., "The Circular Economy: A Review of Definitions, Processes and Impacts."
[2] "Circular Economy Principles." Ellen MacArthur Foundation
[3] Ministerie van Infrastructuur en Waterstaat, "Circular Dutch Economy by 2050."
[4] Ministerio del Medio Ambiente, "ROADMAP FOR a CIRCULAR CHILE BY 2040."
[5] Li, "Joint ACI World-ICAO Passenger Traffic Report, Trends, and Outlook | ACI World."
[6] "2024 Global Market Forecast," Airbus
[7] Brown, "Circularity in Flight."
[8] "Repurpose With Purpose | Southwest Airlines."
[9] Emirates, "Emirates Unveils New Closed Loop Recycling Initiative to Reduce Plastic," April 3, 2024
[10] "Pioneer Project - AEROPORTI DI ROMA - Aeroporti Di Roma."
[11] "Zero Waste Case Study: San Diego International Airport (Detailed) | US EPA," US EPA, April 14, 2025